8/PRTS

09/744227

JC02 Rec'd PCT/PTO 22 JAN 2001

DESCRIPTION

Method of Producing Gas Discharge Panel

FIELD OF THE INVENTION

The present invention relates to the method of producing the gas discharge panel such as the plasma display panel used for displaying images on computer and TV monitors.

BACKGROUND OF THE INVENTION

An explanation of the conventional plasma display panel will be given with reference to figures. Fig. 8 is a simplified sectional view of the AC plasma display panel (hereinafter, referred to "PDP").

In Fig. 8, a reference number 110 indicates a front glass plate. On the front glass plate 110, display electrodes 111 are formed. The display electrodes 111 are covered by a dielectric glass layer 112 and a dielectric protection layer 113 made of magnesium oxide (MgO) (refer to Japanese Patent Laid-Open Publication No. 5-342991).

Meanwhile, a reference number 120 indicates a back glass plate. On the back glass plate 120, address electrodes 121, a visible light reflective layer 122 for covering the address electrodes 121, partition walls 123,

and phosphor layers 124 are disposed. A reference number 130 indicates a discharge space filled with a discharge gas. For color display, each of the phosphor layers 124 is red, green or blue and the phosphor layers 124 are disposed in this order. Each of the phosphor layers 124 is excited by short ultraviolet light of a short wavelength (for instance, 147nm) that has been generated by discharge and emits light.

Generally, the phosphors described below are used for the phosphor layers 124.

"Blue phosphor": $BaMgAl_{10}O_{17}:Eu$

"Green phosphor": $Zn_2SiO_4:Mn$ or $BaAl_{12}O_{19}:Mn$

"Red phosphor": $Y_2O_3:Eu$ or $(Y_xGd_{1-x})BO_3:Eu$

Now, the method of producing each of the phosphors will be described.

The blue phosphor ($BaMgAl_{10}O_{17}:Eu$) is manufactured as follows. First, barium carbonate ($BaCO_3$), magnesium carbonate ($MgCO_3$), and aluminium oxide (α-Al_2O_3) are blended so that the atomic ratio of barium (Ba), magnesium (Mg), and aluminium (Al) is 1:1:10.

Next, a predetermined amount of europium oxide (Eu_2O_3) is added to the mixture. Then, the mixture is blended with an appropriate amount of flux (AlF_2, $BaCl_2$) in a ball mill. The mixture that has been blended with the flux is calcinated at 1400 to 1650℃ for a predetermined amount of time (for instance, 0.5 hours) in

a reducing atmosphere (in H_2 or N_2) to obtain the blue phosphor.

The red phosphor (Y_2O_3:Eu) is manufactured as follows. The raw materials for the red phosphor, yttrium hydroxide ($Y_2(OH)_3$) and boric acid (H_3BO_3) are blended so that the atomic ratio between yttrium and boric is 1:1. Then, a predetermined amount of europium oxide (Eu_2O_3) is added to the mixture. The mixture is blended with an appropriate amount of flux in a ball mill and is calcinated at 1200 to 1450℃ for a predetermined amount of time (for instance, 1.0 hour) in the air to obtain the red phosphor.

The green phosphor (Zn_2SiO_4:Mn) is manufactured as follows. The raw materials for the green phosphor, zinc oxide (ZnO) and silicon oxide (SiO_2) are blended so that the atomic ratio between zinc and silicon is 2:1. Then, a predetermined amount of manganese oxide (Mn_2O_3) is added to the mixture and blended in a ball mill. The mixture is calcinated at 1200 to 1350℃ for a predetermined amount of time (for instance, 0.5 hours) in the air to obtain the red phosphor.

Particles of each of the phosphors that has been obtained in the above-described method are grounded to powders and then sieved to obtain phosphor materials having a predetermined particle distribution.

Here, an explanation of the conventional

producing method of PDP will be given below.

First, display electrodes are formed on the front glass plate. The dielectric layer made of a dielectric glass is formed so as to cover the display electrodes. On the dielectric layer, the protection layer is formed made of MgO. Then, the address electrodes are formed on the back glass plate. On the address electrodes, the visible light reflective layer made of a dielectric glass is formed. On the address electrodes, glass partition walls are formed with a predetermined pitch.

In the spaces between the partition walls, phosphor pastes which each include the red, green, and blue phosphors are put, respectively to form the phosphor layer. The phosphor layer is calcinated at approximately 500℃ to remove the resin component and the like in the pastes (the phosphor calcination process).

After the phosphor calcination, a glass frit for sealing the apertures between the front and back glass plates is applied onto the outer edge of the back glass plate, and the back glass plate is calcinated at 350℃ (the glass calcination process for sealing).

Then, the front glass plate on which the display electrodes, the dielectric glass layer, and the protection layer have been formed in order and the back glass plate are positioned so as to face each other. In this case, the front and back glass plates are positioned

so that the display electrodes and the address electrodes intersect orthogonally via the partition walls. Then, the front and back glass plates are calcinated at 450℃ to seal the front and back glass plates along the outer edges with sealing glass (the sealing process).

After the sealing process, while the panel is heated to a predetermined temperature (approximately 350℃), the air is exhausted from the panel (the exhaust process). After the exhaust process, the panel is filled with the discharge gas at a predetermined pressure.

In the above-described producing method of PDP, the light emitting properties gradually deteriorate after panel production, in the aging process for stabilizing the discharge properties, and in the normal operation. This is problematic.

This is because impurities (gas components different from the discharge gas such as water vapor, oxygen, nitrogen, and carbon dioxide) in the internal spaces are not completely cleaned and remain in the internal spaces in the exhaust process.

DISCLOSURE OF THE INVENTION

It is accordingly the object of the present invention to provide a method of producing a gas discharge panel that efficiently exhausts gas in the vacuum pumping process, which is necessary to the panel

producing processes.

The above-mentioned object may be achieved by a method of producing a gas discharge panel that includes: an envelope forming step for forming an envelope by providing over a first plate a second plate so that the second plate faces a main surface of the first plate, on which partition walls for partitioning light emitting cells have been formed; a sealing step for sealing the envelope with a sealant along outer edges of the first and second plates; an exhaust step for exhausting gas from the envelope; and a filling step for filling the envelope with a discharge gas, wherein the exhaust step includes: a substep for evacuating the envelope; a substep for filling the envelope with a cleaning gas that includes as a constituent a gas that substantially causes no impurity in the discharge gas; and a substep for re-evacuating the envelope.

The above-mentioned object may be also achieved by a method of producing a gas discharge panel that includes: an envelope forming step for forming an envelope by providing over a first plate a second plate so that the second plate faces a main surface of the first plate, on which partition walls for partitioning light emitting cells have been formed; a sealing step for sealing the envelope with a sealant along outer edges of the first and second plates; an exhaust step for

exhausting gas from the envelope; and a filling step for filling the envelope with a discharge gas, wherein the exhaust step includes: a substep for evacuating the envelope; and a substep for exhausting gas from the envelope while a cleaning gas is circulated through the envelope, the cleaning gas including as a constituent a gas that substantially causes no impurity in the discharge gas.

Note that the "includes as a constituent a gas that substantially causes no impurity in the discharge gas" means that "the major constituent of the cleaning gas causes no impurities in the discharge gas".

Unlike the conventional method, gas is not only exhausted from the envelope as in the case of the conventional producing method. According to these producing methods, gas is exhausted from the envelope after the envelope is filled with the cleaning gas or while the cleaning gas is circulated through the envelope. As a result, the concentration of impurity gas in the envelope can be swiftly (in a short period of time) lowered compared with the conventional method.

Also, when the pressure in the envelope is set to be lower than the pressure outside of the envelope while the entire envelope or the sealed part is heated to a temperature that is no lower than the softening point or the melting point of the sealant at the sealing step in

the producing methods, the sealant hardens to seal the envelope while the first and second plates are evenly pressed from the outside due to the pressure difference between the inside and the outside of the envelope. As a result, the envelope is sealed so that the entire top ends of the partition walls almost come in contact with the plate that faces the partition walls. According to the conventional method, the pressures inside and outside of the envelope are not set to be different and only the outer edges are tightly held with clips, so that the central parts of the first and second plates of the envelope are not pressed. As a result, the entire or part of the top ends of the partition walls tends to be apart from the facing plate when the envelope is sealed.

Accordingly, it is easy to produce a PDP with rare vibration at the time of drive and with excellent display quality according to the methods described above.

Also, when the envelope is filled with the dry gas at the sealing step, heat deterioration of the phosphors can be prevented.

<u>BRIEF DESCRIPTION OF THE DRAWINGS</u>

These and other objects, advantages and features of the invention will become apparent from the following description thereof taken in conjunction with the accompanying drawings that illustrate a specific

embodiment of the invention. In the Drawings:

Fig. 1 is a perspective view showing the structure of an AC plasma display panel (PDP) according to the embodiments of the present invention;

Fig. 2 shows the structure of a display device that is the PDP equipped with a circuit block;

Fig. 3 is diagrammatic sketches of a sealing/exhausting device 50 used in a sealing process of the first embodiment;

Fig. 3(a) is an overhead cutaway view of the seal/exhaust device 50;

Fig. 3(b) is a vertical sectional view taken on line A-A' of Fig. 3(a);

Fig. 4 shows temperature and pressure profiles during sealing (practical example);

Fig. 5 shows temperature and pressure profiles in an vacuum pumping/filling process (practical example);

Fig. 6 shows temperature and pressure profiles during sealing and in the vacuum pumping/filling process (practical example);

Fig. 7 is a diagrammatic sketch of a sealing/exhausting device 70 used in a sealing process of the second embodiment; and

Fig. 8 is a perspective view showing the structure of a PDP according to a conventional example.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A specific explanation of a producing method of a PDP according to the present invention will be given below with reference to figures.

[Overall Structure and Producing Method of PDP]

Fig. 1 is a perspective view showing the structure of an AC surface discharge type PDP according to the embodiments of the present invention. Fig. 2 shows the structure of a display device that is the PDP equipped with a circuit block.

In the PDP, pulsed voltage is applied between the electrodes for discharge in the discharge spaces. Along with the discharge, visible lights of different colors are generated on the side of the back panel. The visible lights is emitted through the front panel.

The PDP is composed of a front panel 10 and a back panel 20. The front panel 10 is formed by disposing a plurality of display electrodes 12 (scan electrodes 12a and sustain electrodes 12b), a dielectric layer 13, and a protection layer 14 on a front glass plate 11. On the other hand, the back panel 20 is formed by disposing a plurality of address electrodes 22 and dielectric layer 23 on a back glass plate 21. The front and back panels are positioned so that the scan and sustain electrodes 12a and 12b and the address electrodes 22 face to each

other at a distance.

The center of the PDP is an area for displaying an image. The space between the front and back panels 10 and 20 are separated by a plurality of partition walls 24 that run in parallel to form a plurality of discharge spaces 30. The discharge spaces 30 are filled with discharge gas. In each of the discharge spaces 30, a phosphor layer 25 is disposed on the back panel 20. Different color phosphor layers 25, i.e., red, green, and blue phosphor layers 25 are repeatedly arranged in this order.

The display electrodes 12 and the address electrodes 22 are disposed in parallel, respectively. The display electrodes 12 are disposed orthogonally to and the address electrodes 22 in parallel to the partition walls 24.

As a result, cells which each emit red, green, and blue lights are formed where the display electrodes 12 and the address electrodes 22 intersect in the panel.

The dielectric layer 13 covers the entire surface of the front glass plate 11 on which the display electrodes 12 are disposed. The dielectric layer 13 is made of a dielectric substance. Low melting point lead glass is generally used. Low melting point bismuth glass, or layers of low melting point lead glass and low melting point bismuth glass may be also used.

The protection layer 14 is a thin film made of magnesium oxide (MgO). The protection layer 14 covers the entire surface of the dielectric layer 13. Having the function of the visible light reflective layer, TiO_2 particles are blended in the dielectric layer 23. The partition walls 24 are made of a glass material and are disposed on the surface of the dielectric layer 23 of the back panel 20 in a protruding condition.

Meanwhile, the front and back panels 10 and 20 are sealed with a sealant along the outer edge of the PDP.

The entire top ends of the partition walls 24 approximately come in contact with or are joined to the front panel 10 with a bonding material.

Here, an example of a producing method of the above-described PDP will be described.

(Manufacturing Front Panel)

The display electrodes 12 are formed on the front glass electrode 11. The dielectric layer 13 is formed so as to cover the display electrodes 12 and the front glass electrode 11. Then, on the surface of the dielectric layer 13, the protection layer 14 made of MgO is formed in the vacuum evaporation method, the electron beam evaporation method, or the CVD (Chemically Vapor Deposition) method. In this manner, the front panel is

manufactured.

The display electrodes 12 are formed by applying a silver electrode paste on the front glass electrode in the screen printing method and calcinating the paste. Also, silver electrodes may be formed after forming transparent electrodes with ITO (Indium Tin Oxide) or SnO_2 (tin dioxide), or Cr-Cu-Cr electrodes may be formed in the photo photolithographic method.

The dielectric layer 13 can be formed by applying a paste including a lead glass material (the composition is 70wt% of lead oxide (PbO), 15wt% of (B_2O_3), and 15wt% of silicon oxide (SiO_2), for instance) on the front glass plate 11 in the screen printing method and calcinating the paste.

(Manufacturing Back Panel)

On the back glass plate 21, the address electrodes 22 are formed in the screen printing method as in the case of the display electrodes 12.

Then, the dielectric layer 23 is formed by applying a glass material with which TiO_2 particles have been blended on the back glass plate 21 in the screen printing method and calcinating the paste.

Next, the partition walls 24 are formed. The partition walls 24 are formed by applying a partition wall glass paste on the back glass plate 21 in the screen

printing method and calcinating the paste. The partition walls 24 can be also formed by applying a partition wall glass paste on the entire surface of the back glass plate 21 and removing the paste from the parts where the partition walls 24 are not formed in the sand blast method.

In the channels between the partition walls, the phosphor layers 25 are formed. Generally, the phosphor layers 25 are formed by applying the phosphor pastes each of which includes phosphor particles of a different color in the screen printing method and calcinating the applied phosphor pastes. The phosphor layers 25 may be formed by continuously spraying phosphor inks from a nozzle on the channels while the nozzle scans the channels and calcinating the phosphor inks in order to remove the solvents and binders included in the phosphor inks. In each of the phosphor inks, phosphor particles of a different color are dispersed in a mixture of a binder, a solvent, a dispersant, and the like. The phosphor inks are adjusted so as to have an appropriate viscosity.

The following is specific examples of the phosphor particles.

Blue phosphor: $BaMgAl_{10}O_{17}:Eu^{2+}$

Green phosphor: $BaAl_{12}O_{19}:Mn$ or $Zn_2SiO_4:Mn$

Red phosphor: $(Y_xGd_{1-x})BO_3:Eu^{3+}$ or $YBO_3:Eu^{3+}$

In the preferred embodiments of the present

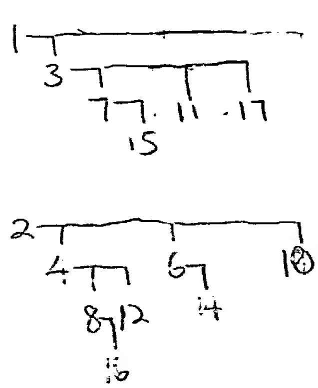
invention, the height of the partition walls is set to be 0.06 to 0.15mm and the pitch between the partition walls is 0.13 to 0.36mm in line with the Video Graphics Array (VGA) and high-definition TV set of 40 inch class.

(Sealing Process, Vacuum Pumping Process, and Discharge Gas Filling Process)

Next, the front panel 10 and the back panel 20 are sealed.

In the sealing process, the front panel 10 is provided on the back panel 20 and a sealant is inserted between the front panel 10 and the back panel 20 along the outer edges to form an envelope. The apertures between the front panel 10 and the back panel 20 along the outer edges are sealed with the sealant. When necessary, a bonding material can be applied on the top of the partition walls of the back panel 20.

The sealant is a material that is softened by energy such as heat from outside. Generally, low-melting glass is used as the bonding material. In the sealing process, the sealant is softened by heat and then hardened.



sures

be

he front

de. By

doing so, the entire top ends of the partition walls 24 come in contact with or come closer to the front panel 10 in the sealing.

After the sealing process, a high vacuum (1.3×10^{-11}MPa, for instance) is produced in the internal space to exhaust air in order to expel impurity gas that has been absorbed in the inside of the envelope (vacuum pumping process).

Then, the envelope is filled with a discharge gas (He-Xe, Ne-Xe, and Ar-Xe inert gas, for instance) at a predetermined pressure (discharge gas filling process). By doing so, the PDP is produced.

Note that Xe constitutes approximately 5vol% of the discharge gas and the pressure for filling is set in the range of 0.067 to 0.11Mpa in the preferred embodiments of the present invention

When driven for display, the PDP is equipped with a circuit block as shown in Fig. 2.

Explanations of the sealing process, the vacuum pumping process, and the discharge gas filling process will be given below in the first to fourth embodiments.

(The First Embodiment)

Fig. 3 is diagrammatic sketches of a sealing/exhausting device 50 used in the sealing process

of the first embodiment. Fig. 3(a) is an overhead cutaway view of the sealing/exhausting device 50 and Fig. 3(b) is a vertical sectional view taken on line A-A' of Fig. 3(a).

In the sealing/exhausting device 50, the envelope 40, which is formed by providing the front panel 10 on the back panel 20, is enclosed. The sealing/exhausting device 50 also includes a heating furnace 51 for applying heat to the envelope 40, a gas introducing system 52 that is equipped outside of the heating furnace 51, and a suction exhaust system 53.

To the heating furnace 51, heat can be applied by a heater 54. The internal temperature can be set at a desired temperature.

The sealing process is performed using the sealing/exhausting device 50 as follows.

As shown in Fig. 3, ventilation slots 21a and 21b are opened in advance in the back panel 20 at the regions that are positioned outside of the display area. The ventilation slot 21a is opened at the upper right of the back panel 20, while the ventilation slot 21b is at the bottom left in Fig. 3(a).

A paste including a sealant is applied to at least one of the joining surfaces of the front panel 10 and the back panel 20 along the outer edges. Then, the paste is calcinated to form a sealant layer 41. Here, a

low-melting glass having a softening temperature lower than the materials of the dielectric layer 23 and the partition wall 24 is used as the sealant. Note that the sealant is not limited to the low-melting glass. Metals can be used. In this case, the temperature for sealing is the temperature at which the metal melts. Accordingly, the sealing temperature is higher than the melting point.

A specific example of the low-melting glass is the mixture of 80wt% of a low-melting glass frit (the softening temperature is 370℃), 5wt% of an ethyl cellulose binder, and 15wt% of isoamyl acetate. By applying the mixture with a dispenser, the sealant layer 41 is formed.

Between the sealant layer 41 and the outermost partition walls, partition members 42 are disposed so as to halve the spaces between the sealant layer 41 and the partition walls 24. The material of the partition members 42 can be the same as the material of the sealant layer 41 and the partition walls 24. Due to the partition members, gas is effectively introduced into and exhausted from the discharge spaces between the partition walls 24. Note that the partition members 42 cannot be disposed.

Then, the front panel 10 is provided on the back panel 20 to form the hosing 40 while it is checked that

the front and back panels 10 and 20 are properly positioned. The outer edge of the envelope 40 is tightly held with clips (not illustrated) so that the front and back panels 10 and 20 do not shift the positions.

The envelope 40 is set inside of the heating furnace 51. Then, the gas introducing system 52 is connected to the ventilation slot 21a of the envelope 40 via a connecting tube 55. On the other hand, the suction exhaust system 53 is connected to the ventilation slot 21b of the envelope 40 via a connecting tube 56.

The connecting tubes 55 and 56 are glass tubes that are fixed to the back panel 20 at the lower surface via bonding members 55a and 56a. The material of the bonding members 55a and 56a is the same as the material of the sealant layer 41. More specifically, a paste including the low-melting glass is applied to the back panel 20 with a dispenser. Then, the paste is dried and the connecting tubes 55 and 56 are tentatively fastened to the back panel 20 with clips. By doing so, as the sealant layer 41 is softened and hardened to seal the envelope, the bonding members 55a and 56a are also softened and hardened. As a result, the connecting tubes 55 and 56 are connected to the ventilation slots 21a and 21b and the apertures between the connecting tubes 55 and 56 and the ventilation slots 21a and 21b are sealed.

The gas introducing system 52 includes a gas bomb

52a and a pipe system 52b, which connects the gas bomb 52a to the connecting tube 55. In the midst of the pipe system 52b, an open/close valve 52c is disposed for adjusting the amount of gas to be introduced. The connecting tube 55 and the pipe system 52b are connected to each other with a chuck so as to ensure airtightness.

The suction exhaust system 53 includes a manifold 53a, a turbo-molecule pump 53b, a rotary pump 53c, and pipe systems 53d and 53e. The pipe system 53d connects the connecting tube 56 to the manifold 53a. On the other hand, the pipe system 53e connects the manifold 53a to the turbo-molecule pump 53b. In the midst of the pipe system 53e, an open/close valve 53f is disposed for adjusting the amount of gas sucked out by the turbo-molecule pump 53b. The connecting tube 56 and the pipe system 53d are connected to each other with a chuck so as to ensure airtightness.

Note that the front panel 10 is provided on the back panel 20 in the present embodiment. However, the back panel 20 may be provided on the front panel 10 instead. Also, as long as the front and back panels 10 and 20 are held together so as not to shift the positions, the envelope 40 can be vertically set in the heating furnace.

The heating furnace 51 is heated to the sealing temperature that is slightly higher than the softening

temperature of the sealant (for instance, 450℃). Then, the heating furnace 51 is kept at the sealing temperature for a certain period of time and the temperature is lowered to a temperature that is no higher than the softening temperature. By doing so, the apertures between the front and back panels 10 and 20 are sealed. In the sealing, gas is being exhausted from the envelope 40 by the turbo-molecule pump 53b. Note that when the turbo-molecule pump 53b is actuated, the rotary pump 53c is simultaneously actuated to lower the back pressure in the turbo-molecule pump 53b. The condition for sealing is determined by the compatibility between the material of the glass plates and the sealant. When the low melting point glass is used, the sealing condition is approximately 10 to 20 minutes around 450℃.

It is preferable to start the exhaust after the temperature in the heating furnace 51 reaches the softening temperature of the sealant. Before the temperature reaches the softening temperature, the airtightness of the outer edges of the front and back panels 10 and 20 is not high enough to produce a high vacuum in the envelope 40 even if gas is exhausted from the envelope 40. On the other hand, after the sealant is softened, the apertures between the front and back panels 10 and 20 along the outer edges are sealed. Also, the bonding member 55a is softened to seal the apertures

between the connecting tube 55 and the ventilation slot 21a. As a result, when the gas is exhausted from the envelope 40, the pressure is reduced to produce a high vacuum (approximately 1.33×10^{-4}MPa, i.e., approximately several Torr).

By exhausting gas from the envelope 40 as has been described, pressure is evenly applied to the front and back panels 10 and 20 from the outside. The degree of suction and exhaust by the suction exhaust system 53 is enough when the sealant is pressed to shrink due to the difference between the pressures in the envelope 40 and in the heating furnace and the front and back panels come to closer to each other so that the front panel touches the partition walls. For this reason, the suction and exhaust is slightly performed (for instance, approximately 0.08MPa).

When pressure is evenly applied to the front and back panels 10 and 20 from the outside, the front panel 10 comes into contact with the top ends of the partition walls on the back panel 20 as shown in Fig. 3. When the temperature is lowered in this state, the temperature of the sealant becomes lower than the softening temperature and the sealant hardens to seal the envelope 40. As a result, the front panel 10 and the entire top ends of the partition walls are kept in absolute contact in the sealed envelope 40.

Note that the temperature is increased not at one stroke to the sealing temperature that is slightly higher than the softening temperature of the sealant in the sealing process. The temperature is kept at lower than the sealing temperature for a certain period of time, for instance, at around 350℃ for 30 minutes, to burn out the binder material. This is effective at preventing the phosphor from deteriorating.

When the envelope 40 is sealed as has been described, the next processing advances to the vacuum pumping process.

In the vacuum pumping process, the inside of the heating furnace 51 is heated (baked) at a temperature (exhaust baking temperature) that is lower than the softening temperature of the sealant layer. In this heating, the open/close valve 53f is opened at an appropriate degree, and the turbo-molecule pump 53b and the rotary pump 53c are actuated so as to evacuate the envelope 40. Then, the discharge gas is introduced into the envelope 40 from the gas introducing system 52 with a predetermined pressure (for instance, 0.05MPa). It is preferable to keep the pressure for a predetermined period of time (5 to 10 minutes) after the envelope 40 is filled with the discharge gas. This is because it takes a certain period of time to reach the equilibrium pressure since the conductance between the partition

walls in the envelope is small.

Note that it is preferable to perform the vacuum pumping process at the baking temperature as has been described since the impurity that has been absorbed into the interior wall of the envelope 40 tends to fill the discharge space in gaseous form. In this situation, the impurity can be expelled from the envelope more swiftly. For this reason, the evacuation is generally performed at the exhaust baking temperature. The evacuation, however, is not limited to this case. Merely the evacuation can be performed.

Also, the exhaust baking temperature is lower than the softening temperature of the sealant. When a metal is used as the sealant, the softening temperature is lower than the melting point of the metal. Here, the exhaust baking temperature is a temperature that is effective at removing the absorbed water that has been absorbed into the interior wall of the envelope 40 (for instance, around 350℃).

The vacuum pumping process can start after the temperature of the envelope 40 is lowered to the room temperature. It is preferable, however, to start the vacuum pumping process when the sealing temperature in the sealing process is lowered to the exhaust baking temperature. This is because the manufacturing process can be shortened since the period of time to re-increase

the lowered temperature to the exhaust baking temperature is saved.

Then, the discharge gas introduction from the gas introducing system 52 is stopped and the discharge gas is sucked out from the envelope with the suction exhaust system 53 to re-establish a vacuum state in the envelope 40 again.

Usually, it is enough to perform a series of processes of vacuum pumping, discharge gas introduction, and vacuum pumping only once. When the series of processes is repeated, however, the impurity gas concentration is further lowered in the envelope 40.

Here, the gas introduced into the envelope 40 is not limited to discharge gas. Any kind of gas can be used as long as the gas is not any impurity gas for the discharge gas. Not clearly defined, the impurity is a kind of gas that lowers the intensity. Also, it is preferable that the gas to be introduced is a dry gas since the phosphor is prevented from deteriorating. Here, the dry gas is a gas that has a partial pressure of water vapor lower than the ordinary gas. For instance, the partial pressure of water vapor (dew point) is no higher than 0.0027MPa (22℃).

The pressure that is to be introduced into the envelope 40 after evacuation can be from around 1.33×10^{-4}MPa (several Torr) to the maximum pressure with which

the envelope 40 is not broken. It is preferable that the pressure is lower than the atmospheric pressure.

The next process is the discharge gas filling process. In the discharge gas filling process, the discharge gas is supplied to the internal space of the envelope 40 by the gas introducing system 52 so as to have a predetermined pressure for filling (for instance, 0.067MPa). Then, the connecting tubes 55 and 56 are molten with a burner or a heater where the connecting tubes 55 and 56 are fixed to the back panel 20 to be sealed off (chipped off). As a result, the ventilation slots 21a and 21b are sealed.

[Effects of Producing Method of the First Embodiment]

When the pressure is set to be the same inside and outside of the envelope 40 and the envelope 40 is tightly held along the outer edge as in the case of the conventional producing method, pressure is not applied to the central parts of the front and panel of the envelope 40. As a result, a part or the entire part of the top ends of the partition walls on the back panel 20 tends not to come in contact with the front panel 10 when the envelope 40 is sealed. On the other hand, the sealant layer 41 is hardened to seal the envelope 40 while pressure is evenly applied to the front and back panels 10 and 20 from the outside as has been described in the

present embodiment. As a result, the front panel 10 almost comes into contact with the top ends of the partition walls when the envelope 40 is sealed.

Accordingly, it is easy to produce a PDP with rare vibration at the time of drive and with excellent display quality according to the producing method of the present embodiment.

In order to obtain these effects, it is at least necessary to actuate the suction exhaust system so as to set the pressures inside and outside of the envelope to be different when the softened sealant layer 41 is hardened. It is not necessary, however, to successively actuate the suction exhaust system 53 from the start to the end of the sealing process. For instance, when the suction exhaust system 53 starts to be actuated after the sealant layer 41 is softened, the effects due to the pressure difference between the inside and outside of the front and back panels 10 and 20 can be sufficiently obtained.

Also, as a result of the vacuum pumping process, the impurity gas concentration can be swiftly lowered.

This can be a result of 1) the effect of diluting impurity gas by filling the envelope with a large amount of discharge gas, 2) the effect of exhausting residual impurity gas from the envelope 40 by the viscous flow at the time of the gas filling and gas re-exhausting, 3) the

effect of removing absorbed gas by collision of discharge gas molecules with the internal wall of the envelope 40 such as the phosphors and the protection layer, and the like. According to the third effect, it is preferable to use a gas that has been heated as the discharge gas (cleaning gas) to be introduced into the envelope in the vacuum pumping process.

After the envelope 40 is evacuated while the temperature is kept at the exhaust baking temperature, the residual gas in the discharge space surrounded by the partition walls is not sufficiently exhausted from the envelope 40. For instance, suppose that the height of the partition walls in the envelope 40 is 120μm, the pitch between the partition walls is 200μm, the diameter of the slot for exhaust is approximately 2mm, the internal diameter of the connecting tube 56 is approximately 2mm, and the length of the connecting tube 56 is approximately 90mm. In this case, when the gas is exhausted at the exhaust baking temperature of 350℃, the pressure inside of the envelope 40 is 10 to 20 times the pressure inside of the manifold 53a even if the pressure inside of the manifold 53a is approximately 1.3×10^{-11} to 1.3×10^{-10}MPa.

Of course, when the period of time for baking is lengthened, the amount of water and impurity gas that have been absorbed into the interior wall of the envelope

40 is reduced. The manufacturing cost is instead raised.

In the vacuum pumping process that has been described, after filled with the discharge gas, the envelope 40 is evacuated again. The impurity gas can be removed more swiftly according to the method described below.

While the envelope 40 is being filled with the discharge gas introduced by the gas introducing system 52, the discharge gas is exhausted from the envelope 40 with the suction exhaust system 53. The flow of the discharge gas is shown by large arrows in Fig. 3(a). B doing so, the discharge gas flows in the envelope 40, so that the impurity gas can be removed more efficiently. Especially, the impurity gas in the discharge space apart from the exhaust hole (the ventilation slot 21b) is effectively exhausted from the innermost part in the envelope 40.

In this case, it is possible to fill the envelope 40 with the discharge gas without evacuating the envelope 40 before the filling process.

(The First Practical Example)

A specific explanation of the first practical example of the PDP producing method in which each of the processes is performed according to the first preferred embodiment will be given below.

Fig. 4 shows temperature and pressure profiles during sealing. Fig. 5 shows temperature and pressure profiles in an vacuum pumping/filling process. In the first practical example, the PDP is manufactured according to each of the profiles. Note that the dotted line in Figs. 4 and 5 shows the temperature of the envelope 40 while the solid line the pressure change in the manifold 53a.

The sealing process will be explained first. The temperature is increased to the sealing temperature, 450℃ in two to three hours, and the sealing temperature is kept for about 20 minutes. Meanwhile, when the temperature reaches 450℃, the pressure in the manifold 53a is lowered to around 0.05MPa and the suction exhaust system is stopped and remains stopped.

Then, while the lowered pressure is kept, the temperature is decreased to the room temperature in two to three hours.

At this stage, the front and back panels have been sealed.

Next, as shown in Fig. 5, the evacuation is continued and heating is started after the pressure in the manifold 53a becomes around 1.3×10^{-11} to 1.3×10^{-10}MPa. The temperature is increased to the exhaust baking temperature (350℃) in two to three hours. When the temperature reaches the exhaust baking temperature, the

evacuation is started again to exhaust the gas that has circulated into the manifold during the temperature increase. When the evacuation is resumed, the pressure in the manifold 53a rises as indicated by an arrow 60 in Fig. 5 due to the gas removed from the interior walls of the connecting tube 56 and the envelope 40. At the start of the evacuation, however, the pressure begins lowering.

Then, when the pressure in the manifold 53a reaches around $1.3x10^{-11}$ to $1.3x10^{-10}$MPa, the suction exhaust system 53 stops and the gas introducing system 52 is actuated. The envelope 40 is filled with the discharge gas with around 0.05MPa of pressure and the pressure is kept for five to 10 minutes.

After that, in the course of cooling, gas starts to be evacuated from the envelope 40. After the pressure reaches around $1.3x10^{-11}$ to $1.3x10^{-10}$, the gas introducing system 52 fills the envelope 40 with the discharge gas with 0.067MPa of pressure.

In the conventional vacuum pumping process, it takes around two hours to lower the pressure in the envelope to $1.3x10^{-11}$ to $1.3x10^{-10}$. On the other hand, pressure can be lowered more swiftly in the vacuum pumping process of the first practical example. More specifically, it takes about one hour.

Here, the pressure can be lowered in a short period of time by increasing the driving force of the

pump system of the suction exhaust system and evacuating the envelope more powerfully. In this case, however, the phosphors in the envelope come off the phosphor layers, for instance, leading to panel property deterioration. For this reason, the manifold is disposed as has been described to weaken the force of suction to evacuate the envelope. As a result, it takes a relatively long period of time to lower the pressure in the envelope in the conventional vacuum pumping process.

For the PDP that has been produced according to the above-mentioned method, lifting rarely occurs in the outer regions. Also, the discharge properties are even compared with the conventional method in which pressure is applied only with clips. The level of noise from the outer regions is reduced by approximately several to 10db. The voltage at the start of discharge decreases by approximately 5 to 10V. Furthermore, the discharge current decreases by approximately several to 10% and the effectiveness improves by around 10%.

(The Second Practical Example)

An explanation of the second practical example of the PDP producing method in which each of the processes is performed according to the first preferred embodiment will be given below.

Fig. 6 shows temperature and pressure profiles

during the sealing and in the vacuum pumping/filling process. In the second practical example, the PDP is produced according to the profiles. Note that dotted line in Fig. 6 shows the temperature of the envelope 40 while the solid line the pressure change in the manifold of the suction exhaust system connected to the envelope 40.

The sealing process will be explained first. The temperature is increased to the sealing temperature, 450℃ in two to three hours, and the sealing temperature is kept for about 20 minutes. Meanwhile, when the temperature reaches 450℃, the pressure in the manifold 53a is lowered to around 0.05MPa and the suction exhaust system is stopped and remains stopped.

Then, while the lowered pressure is kept, the temperature is decreased to the exhaust baking temperature (350℃) in 30 minutes.

At this stage, the front and back panels have been sealed. When the pressure in the manifold 53a is monitored as the temperature is decreased, defective sealing can be detected and dealt with in the early stage of the producing process to help lower the cost.

Next, after the temperature is decreased to the exhaust baking temperature, the evacuation is continued to lower the pressure in the manifold 53a to 1.3×10^{-11} to 1.3×10^{-10}MPa. Then, the suction exhaust system 53 is

stopped and the gas introducing system 52 is actuated to fill the envelope 40 with the discharge gas with 1.15MPa of pressure. The pressure is kept for five to 10 minutes.

After that, in the course of cooling, gas starts to be evacuated from the envelope 40. After the pressure reaches around $1.3\text{x}10^{-11}$ to $1.3\text{x}10^{-10}$, the gas introducing system 52 fills the envelope 40 with the discharge gas with 0.067MPa of pressure.

In the conventional vacuum pumping process, it takes around two hours to lower the pressure in the envelope to $1.3\text{x}10^{-11}$ to $1.3\text{x}10^{-10}$. On the other hand, pressure can be lowered more swiftly in the vacuum pumping process according to the first embodiment. More specifically, it takes about one hour.

For the PDP that has been produced according to the above-mentioned method, lifting rarely occurs in the outer regions. Also, the discharge properties are even compared with the conventional method in which pressure is applied only with clips. The level of noise from the outer regions is reduced by approximately several to 10db. The voltage at the start of discharge decreases by approximately 5 to 10V. Furthermore, the discharge current decreases by approximately several to 10% and the effectiveness improves by around 10%.

Compared with the first practical example, the

producing method in the second practical example is effective at shortening the period of time from the sealing to the cooling of the envelope 40 and the period of time for heating from the room temperature to the exhaust baking temperature. Also, the phosphor deteriorates less than the first practical example by several percent or so. The quality is slightly better than the first practical example.

(The Second Embodiment)

The second embodiment is different from the first embodiment in the method in the vacuum pumping process.

Fig. 7 is a diagrammatic sketch of a sealing/exhausting device 70 used in the sealing process of the second embodiment. Fig. 7 corresponds to Fig. 3(b).

The sealing/exhausting device 70 encloses the envelope 40, which is formed by providing the front panel 10 on the back panel 20. Also, the sealing/exhausting device 70 includes a heating furnace 71 for heating the envelope 40 and a gas introducing/suction exhaust system 72 that is provided outside of the heating furnace 71.

To the back panel 20, a connecting tube 73 and a getter tube 74 are tentatively fastened via bonding members 73a and 74a so as to connect the ventilation slots 21a and 21b to the internal space, respectively as

in the case of the first embodiment.

The connecting tube 73 is a glass tube that connects to the back panel 20 with an open end. The getter tube 74 is a glass tube that connects to the back panel 20 with a sealed end. At the end of the getter tube 74 corresponding to the exit of the ventilation slot 21b in the back panel 20, a getter enclosing space 74b is formed for enclosing a getter.

The gas introducing/suction exhaust system 72 includes a manifold 72a, a turbo-molecule pump 72b, a rotary pump 72c, a gas bomb 72d, a pipe system 72e, and a branch connection system 72f. The gas bomb 72d is filled with the discharge gas. The pipe system 72e connects the connecting tube 73 to the manifold 72a. The branch connection system 72f connects the manifold 72a to the turbo-molecule pump 72b and the gas bomb 72d. In the branch connection system 72f, a connection system 72f1 from the manifold 72a branches into connection systems 72f2 and 72f3 via a channel selection valve 72g. The connection systems 72f2 and 72f3 are connected to the turbo-molecule pump 72b and the gas bomb 72d, respectively. In the midst of the connection systems 72f2 and 72f3, open/close valves 72h and 72i are disposed. While the open/close valve 72h adjusts the amount of gas sucked out by the turbo-molecule pump, the 72i open/close valve adjusts the amount of flow of

discharge gas. The connecting tube 73 and the pipe system 72e are connected to each other with a chuck so as to ensure airtightness. The channel selection valve 72g selects the connection system 72f2 when the turbo-molecule pump 72b is actuated. On the other hand, the connection system 72f3 is selected when the discharge gas is introduced into the envelope 40 from the gas bomb 72d.

Then, the temperature in the heating furnace 71 is increased to a sealing temperature (for instance, 450℃) that is slightly higher than the softening temperature of the sealant by a heater 75. After kept at the sealing temperature for a certain period of time, the temperature is decreased lower than the softening temperature. By doing so, the apertures between the front and back panels 10 and 20 are sealed. In the sealing, the envelope 40 is evacuated by the turbo-molecule pump 72b from the inside. The condition for sealing is determined by the compatibility between the material of the glass plates and the sealant. When the low melting point glass is used, the sealing condition is approximately 10 to 20 minutes around 450℃.

It is preferable to start the exhaust after the temperature in the heating furnace 71 reaches the softening temperature of the sealant. Before the temperature reaches the softening temperature, the airtightness of the outer edges of the front and back

panels 10 and 20 is not high enough to produce a high vacuum in the envelope 40 even if gas is exhausted from the envelope 40. On the other hand, after the sealant is softened, the apertures between the front and back panels 10 and 20 along the outer edges are sealed. Also, the sealant layer 41 is softened to seal the apertures between the connecting tube 72 and the ventilation slot 21a. As a result, when the gas is exhausted from the envelope 40, the pressure is reduced to produce a high vacuum (approximately 1.33×10^{-4}MPa, i.e., approximately several Torr).

By exhausting gas from the envelope 40 as has been described, pressure is evenly applied to the front and back panels 10 and 20 from the outside. The degree of suction and exhaust is enough when the sealant is pressed to shrink due to the difference between the pressures in the envelope 40 and in the heating furnace and the front and back panels come to closer to each other so that the front panel touches the partition walls. For this reason, the suction and exhaust is slightly performed (for instance, approximately 0.08MPa).

When pressure is evenly applied to the front and back panels 10 and 20 from the outside, the front panel 10 comes into contact with the top ends of the partition walls on the back panel 20 as has been described. When the temperature is lowered in this state, the temperature

of the sealant becomes lower than the softening temperature and the sealant hardens to seal the envelope 40. As a result, the front panel 10 and the entire top ends of the partition walls are kept in absolute contact in the sealed envelope 40.

Next, after the temperature is lowered to the room temperature, an end 74c of the getter tube 74 is broken to insert getter 76. The amount of the getter 76 corresponds to the size of the internal space of the envelope 40. Then, the end 74c is sealed off to enclose the getter 76 into the getter enclosing space 74b. The getter 76 can be a substance the surface of which is activated by heating to irreversibly, chemically absorb the impurity gas. In this case, it is preferable to use a substance that is chemically activated at the exhaust baking temperature later in the vacuum pumping process.

Then, after a vacuum state is re-established in the envelope 40, heating (baking) is started when the temperature in the heating furnace 71 is lower than the softening temperature of the sealant layer (at the exhaust baking temperature).

Also, the exhaust baking temperature is lower than the softening temperature of the sealant. When a metal is used as the sealant, the softening temperature is lower than the melting point of the metal. Here, the exhaust baking temperature is a temperature that

activates the getter 76 and is effective at removing the absorbed water that has been absorbed into the interior wall of the envelope 40 (for instance, around 350℃).

When the temperature reaches the temperature for activating the getter 76 during the temperature increase to the exhaust baking temperature, water and impurity gas such as carbon dioxide, nitrogen, oxygen, and so on are absorbed to the surface of the particle of the getter 76. The absorbed water and impurity gas is taken in the particle pores. This is because of the pressure gradient (gas concentration gradient) between the internal space of the envelope 40 and the getter enclosing space 74b, into which the getter 76 is enclosed, as a result that the impurity gas is taken in the getter 76.

Then, while the temperature is kept at the exhaust baking temperature, the open/close valve 72h is opened to an appropriate degree and the turbo-molecule pump 72b and the rotary pump 72c are activated to further evacuate the envelope 40. After that, the connection system 72f3 is selected with the channel selection valve 72g and the open/close valve 72i is opened to introduce the discharge gas into the envelope 40 with a predetermine pressure (for instance, 0.05MPa). It is more preferable to keep the pressure for a predetermined period of time (five to 10 minutes) after the envelope 40 is filled with the discharge gas. This is because it

takes a certain period of time to reach the equilibrium pressure since the conductance between the partition walls in the envelope 40 is small.

Then, the discharge gas introduction is stopped and the discharge gas is sucked out from the envelope to re-establish a vacuum state in the envelope 40 again.

Usually, it is enough to perform a series of processes of vacuum pumping, discharge gas introduction, and vacuum pumping only once. When the series of processes is repeated, however, the impurity gas concentration is further lowered in the envelope 40.

Here, the gas introduced into the envelope 40 is not limited to discharge gas. Any kind of gas can be used as long as the gas is not impurity for discharge gas. Also, it is preferable that the gas to be introduced is a dry gas since the phosphor is prevented from deteriorating.

The pressure that is to be introduced into the envelope 40 after evacuation can be from around 1.33×10^{-4}MPa (several Torr) to the maximum pressure with which the envelope 40 is not broken. It is preferable that the pressure is lower than the atmospheric pressure.

The next process is the discharge gas filling process. In the discharge gas filling process, the discharge gas is supplied to the internal space of the envelope 40 so as to have a predetermined pressure for

filling (for instance, 0.067MPa). Then, the connecting tubes 73 and the getter tube 74 are molten with a burner or a heater where the connecting tubes 55 and 56 are fixed to the back panel 20 to be sealed off (chipped off). As a result, the ventilation slots 21a and 21b are sealed.

[Effects of Producing Method of the Second Embodiment]

When the pressure is set to be the same inside and outside of the envelope 40 and the envelope 40 is tightly held along the outer edge as in the case of the conventional producing method, pressure is not applied to the central parts of the front and back panels of the envelope 40. As a result, a part or the entire part of the top ends of the partition walls on the back panel 20 tends not to come in contact with the front panel 10 when the envelope 40 is sealed. On the other hand, the sealant layer 41 is hardened to seal the envelope 40 while pressure is evenly applied to the front and back panels 10 and 20 from the outside as has been described in the present embodiment. As a result, the front panel 10 almost comes into contact with the top ends of the partition walls when the envelope 40 is sealed.

Accordingly, it is easy to produce a PDP with rare vibration at the time of drive and with excellent display quality according to the producing method of the

present embodiment.

In order to obtain these effects, it is at least necessary to actuate the suction exhaust system so as to set the pressures inside and outside of the envelope to be different when the softened sealant layer 41 is hardened. It is not necessary, however, to successively evacuate the envelope 40 from the start to the end of the sealing process. For instance, when the envelope 40 starts to be evacuated after the sealant layer 41 is softened, the effects due to the pressure difference between the inside and outside of the front and back panels 10 and 20 can be sufficiently obtained.

Also, as a result of the vacuum pumping process, the impurity gas concentration can be swiftly lowered.

This can be a result of 1) the effect of diluting impurity gas by filling the envelope with a large amount of discharge gas, 2) the effect of exhausting residual impurity gas from the envelope 40 by the viscous flow at the time of the gas filling and gas re-exhausting, 3) the effect of removing absorbed gas by collision of discharge gas molecules with the internal wall of the envelope 40 such as the phosphors and the protection layer, and the like. According to the third effect, it is preferable to use a gas that has been heated as the discharge gas (cleaning gas) to be introduced into the envelope in the vacuum pumping process.

Also, in the present embodiment, the process for removing impurity gas in the envelope with the getter is included in the step to increase the temperature to the exhaust baking temperature. As a result, impurity gas can be removed more swiftly and the impurity gas concentration can be further lowered compared with the producing method in the first embodiment, in which only the series of processes of vacuum pumping, discharge gas introduction, and vacuum pumping is performed.

(The Third Practical Example)

A specific explanation of the third practical example of the PDP producing method in which each of the processes is performed according to the first preferred embodiment will be given below.

In the third practical example, the PDP is manufactured according to each of the profiles shown in Figs. 4 and 5. The getter 76 is inserted into the getter tube 74 when the sealing has been performed and the temperature has been lowered to the room temperature. As the getter, vanadium, titanium, and iron alloy particles that are activated at 280℃ are used.

In the conventional vacuum pumping process, it takes around two hours to lower the pressure in the envelope to $1.3x10^{-11}$ to $1.3x10^{-10}$. On the other hand, pressure can be lowered in around one hour in the vacuum

pumping process of the third practical example.

For the PDP that has been produced according to the above-mentioned method, lifting rarely occurs in the outer regions. Also, the discharge properties are even compared with the conventional method in which pressure is applied only with clips. The level of noise from the outer regions is reduced by approximately several to 10db. The voltage at the start of discharge decreases by approximately 5 to 10V. Furthermore, the discharge current decreases by approximately several to 10% and the effectiveness improves by around 10%.

Compared with the first practical example, properties slightly less deteriorates after an aging process (i.e., a process for stabilizing the panel properties after the discharge gas filling process) in the producing method in the third practical example. Also, the producing method is more effective by several percent.

(The Third Embodiment)

The third embodiment is different from the first embodiment in the method in the sealing process.

First, the temperature in the heating furnace 51 is increased to the sealing temperature that is slightly higher than the softening temperature of the sealant (for instance, 450℃). After kept at the sealing temperature

for a predetermined period of time, the temperature is decreased lower than the softening temperature. By doing so, the apertures between the front and back panels 10 and 20 are sealed. While the temperature is increased to the sealing temperature, the gas introducing system is actuated to introduce dry gas into the envelope 40. Note that dried discharge gas with which the gas bomb 52a is charged is used as the dry gas in the third embodiment. Also, dry air, dry nitrogen gas, dry argon gas, dry neon gas (all referred to as noble gas) can be used as the dry gas. When the temperature reaches the sealing temperature, the sealant is softened to ensure the airtightness of the envelope 40. As a result, the internal pressure of the envelope 40 is increased. When the internal pressure increase is monitored, the introduction of the discharge gas is stopped.

Note that the amount of dry gas is limited so that the glass plates of the envelope 40 are not broken due to sharp pressure increase even if the dry gas flows into the envelope 40 when the sealant is softened to seal the envelope 40.

As has been described, the dry gas is composite through the envelope 40 until the temperature reaches the sealing temperature. As a result, when the envelope 40 has been sealed by softened sealant, the envelope 40 is filled with the dry gas. Then, the temperature is kept

at the sealing temperature for a predetermined period of time. The condition for sealing is determined by the compatibility between the material of the glass plates and the sealant. When the low melting point glass is used, the sealing condition is approximately 10 to 20 minutes around 450℃.

In this way, the envelope 40 is sealed while the envelope 40 is filled with the dry gas. By doing so, heat deterioration of the phosphors is prevented.

Furthermore, the temperature is kept at the sealing temperature while the envelope is filled with the dry gas. At the same time, the sealing is performed while the envelope is evacuated with the turbo-molecule pump 53b. Note that when the turbo-molecule pump 53b is activated, the rotary pump 53c is also activated to lower the back pressure in the turbo-molecule pump 53b.

It is preferable to start the exhaust after the temperature in the heating furnace 51 reaches the softening temperature of the sealant.. Before the temperature reaches the softening temperature, the airtightness of the outer edges of the front and back panels 10 and 20 is not high enough to produce a high vacuum in the envelope 40 even if gas is exhausted from the envelope 40. On the other hand, after the sealant is softened, the apertures between the front and back panels 10 and 20 along the outer edges are sealed. Also, the

bonding member 56a is softened to seal the apertures between the connecting tube 56 and the ventilation slot 21b. As a result, when the gas is exhausted from the envelope 40, the pressure is reduced to produce a high vacuum (approximately 1.33×10^{-4}MPa, i.e., approximately several Torr).

By exhausting gas from the envelope 40 as has been described, pressure is evenly applied to the front and back panels 10 and 20 from the outside. The degree of suction and exhaust is enough when the sealant is pressed to shrink due to the difference between the pressures in the envelope 40 and in the heating furnace and the front and back panels come to closer to each other so that the front panel touches the partition walls. For this reason, the suction and exhaust is slightly performed (for instance, approximately 0.08MPa).

When pressure is evenly applied to the front and back panels 10 and 20 from the outside, the front panel 10 comes into contact with the top ends of the partition walls on the back panel 20 as shown in Fig. 3. When the temperature is lowered in this state, the temperature of the sealant becomes lower than the softening temperature and the sealant hardens to seal the envelope 40. As a result, the front panel 10 and the entire top ends of the partition walls are kept in absolute contact in the sealed envelope 40.

Note that the temperature is increased not at one stroke to the sealing temperature that is slightly higher than the softening temperature of the sealant in the sealing process. The temperature is kept at lower than the sealing temperature for a certain period of time, for instance, at around 350℃ for 30 minutes, to burn out the binder material. This is effective at preventing the phosphor from deteriorating.

After the sealing process, the processing advances to the vacuum pumping process, the sealing process, and the discharge gas filling process to produce the PDP as in the case of the first embodiment.

(The Fourth Practical Example)

A specific explanation of the fourth practical example of the PDP producing method in which each of the processes is performed according to the third preferred embodiment will be given below.

In the fourth practical example, the PDP is manufactured according to each of the profiles shown in Figs. 4 and 5.

The sealing process will be explained first. The temperature is increased to the sealing temperature, 450℃ in two to three hours, and the sealing temperature is kept for about 20 minutes. Meanwhile, the dry gas is composite through the envelope 40 by activating the gas

introducing system until the temperature reaches the sealing temperature.

Then, when the temperature reaches 450℃, the gas introducing system is stopped and the pressure in the manifold is lowered to and kept around 0.05MPa.

Next, while the lowered pressure is kept, the temperature is decreased to the room temperature in two to three hours.

At this stage, the front and back panels have been sealed. When the pressure in the manifold is monitored as the temperature is decreased, defective sealing can be detected and dealt with in the early stage of the producing process to help lower the cost. The pressure in the manifold gradually drops when the sealing is normally performed. If the sealing is not normally performed, however, gas is leaked into the heating furnace, so that the pressure drops at a relatively high speed.

Next, as shown in Fig. 5, the evacuation is continued and heating is started after the pressure in the manifold 53a becomes around 1.3×10^{-11} to 1.3×10^{-10}MPa. The temperature is increased to the exhaust baking temperature (350℃) in two to three hours. When the temperature reaches the exhaust baking temperature, the evacuation is started again to exhaust the gas that has flowed into the manifold during the temperature increase.

When the evacuation is resumed, the pressure in the manifold 53a rises as indicated by an arrow 60 in Fig. 5 due to the gas removed from the interior walls of the connecting tube and the envelope 40. At the start of the evacuation, however, the pressure begins lowering.

Then, when the pressure in the manifold 53a reaches around 1.3×10^{-11} to 1.3×10^{-10}MPa, the suction exhaust system 53 stops and the gas introducing system 52 is actuated. The envelope 40 is filled with the discharge gas with around 0.05MPa of pressure and the pressure is kept for five to 10 minutes.

After that, in the course of cooling, gas starts to be evacuated from the envelope 40. After the pressure reaches around 1.3×10^{-11} to 1.3×10^{-10}, the gas introducing system 52 fills the envelope 40 with the discharge gas with 0.067MPa of pressure.

In the conventional vacuum pumping process, it takes around two hours to lower the pressure in the envelope to 1.3×10^{-11} to 1.3×10^{-10}. On the other hand, pressure can be lowered in about one hour in the vacuum pumping process of the fourth practical example.

For the PDP that has been produced according to the above-mentioned method, lifting rarely occurs in the outer regions. Also, the discharge properties are even compared with the conventional method in which pressure is applied only with clips. The level of noise from the

outer regions is reduced by approximately several to 10db. The voltage at the start of discharge decreases by approximately 5 to 10V. Furthermore, the discharge current decreases by approximately several to 10% and the effectiveness improves by around 10%.

Meanwhile, a comparative evaluation of the luminescence intensity (intensity/"y" chromaticity coordinate value) is performed on the phosphors of the PDP that has been sealed after dry gas is circulated as has been described and the PDP that has been sealed while the atmosphere is included in the PDP according to the conventional method. The comparative evaluation is performed by breaking the panel and irradiate Xe excimer lamp (with 173nm of wavelength). The luminescence intensity is improved by around 10% for the blue phosphor. Although the luminescence intensity is improved for all kinds of non-reactive dry gas, significantly improved for dry air.

(The Fifth Practical Example)

A specific explanation of the fifth practical example of the PDP producing method in which each of the processes is performed according to the third preferred embodiment will be given below.

In the fifth practical example, the PDP is manufactured according to each of the profiles shown in

Fig. 6.

The sealing process will be explained first. The temperature is increased to the sealing temperature, 450℃ in two to three hours, and the sealing temperature is kept for about 20 minutes. Meanwhile, the dry gas is circulated through the envelope 40 by activating the gas introducing system until the temperature reaches the sealing temperature.

Then, when the temperature reaches 450℃, the gas introducing system is stopped and the pressure in the manifold is lowered to and kept around 0.05MPa.

Next, while the lowered pressure is kept, the temperature is decreased to the exhaust baking temperature (350℃) in around 30 minutes.

At this stage, the front and back panels have been sealed. When the pressure in the manifold is monitored as the temperature is decreased, defective sealing can be detected and dealt with in the early stage of the producing process to help lower the cost.. The pressure in the manifold gradually drops when the sealing is normally performed. If the sealing is not normally performed, however, gas is leaked into the heating furnace, so that the pressure drops at a relatively high speed.

Next, after the temperature is decreased to the exhaust baking temperature, the evacuation is continued

to lower the pressure in the manifold to $1.3x10^{-11}$ to $1.3x10^{-10}$MPa. Then, the suction exhaust system 53 is stopped and the gas introducing system 52 is actuated to fill the envelope 40 with the discharge gas with 1.15MPa of pressure. The pressure is kept for five to 10 minutes.

After that, in the course of cooling, gas starts to be evacuated from the envelope 40. After the pressure reaches around $1.3x10^{-11}$ to $1.3x10^{-10}$, the gas introducing system fills the envelope 40 with the discharge gas with 0.067MPa of pressure.

In the conventional vacuum pumping process, it takes around two hours to lower the pressure in the envelope to $1.3x10^{-11}$ to $1.3x10^{-10}$. On the other hand, pressure can be lowered more swiftly in the vacuum pumping process according to the first embodiment. More specifically, it takes about one hour.

For the PDP that has been produced according to the above-mentioned method, lifting rarely occurs in the outer regions. Also, the discharge properties are even compared with the conventional method in which pressure is applied only with clips. The level of noise from the outer regions is reduced by approximately several to 10db. The voltage at the start of discharge decreases by approximately 5 to 10V. Furthermore, the discharge current decreases by approximately several to 10% and the

effectiveness improves by around 10%.

Compared with the fourth practical example, the producing method in the fifth practical example is effective at shortening the period of time from the sealing to the cooling of the envelope 40 and the period of time for heating from the room temperature to the exhaust baking temperature. Also, the phosphor deteriorates less than the first practical example by several percent or so. The quality is slightly better than the fourth practical example.

(The Fourth Embodiment)

The fourth embodiment is different from the second embodiment in the method in the sealing process.

First, the temperature in the heating furnace 71 is increased to the sealing temperature that is slightly higher than the softening temperature of the sealant (for instance, 450℃). After kept at the sealing temperature for a predetermined period of time, the temperature is decreased lower than the softening temperature. By doing so, the apertures between the front and back panels 10 and 20 are sealed. While the temperature is increased to the sealing temperature, the gas introducing system is actuated to introduce dry gas into the envelope 40. Note that dried discharge gas with which the gas bomb 72d is charged is used as the dry gas in the third embodiment.

Also, dry air, dry nitrogen gas, dry argon gas, dry neon gas (all referred to as noble gas) can be used as the dry gas. When the temperature reaches the sealing temperature, the sealant is softened to ensure the airtightness of the envelope 40. As a result, the internal pressure of the envelope 40 is increased. When the internal pressure increase is monitored, the introduction of the discharge gas is stopped.

Note that the amount of dry gas is limited so that the glass plates of the envelope 40 are not broken due to sharp pressure increase even if the dry gas flows into the envelope 40 when the sealant is softened to seal the envelope 40.

As has been described, the dry gas is circulated through the envelope 40 until the temperature reaches the sealing temperature. As a result, when the envelope 40 has been sealed by softened sealant, the envelope 40 is filled with the dry gas. Then, the temperature is kept at the sealing temperature for a predetermined period of time. The condition for sealing is determined by the compatibility between the material of the glass plates and the sealant. When the low melting point glass is used, the sealing condition is approximately 10 to 20 minutes around 450℃.

In this way, the envelope 40 is sealed while the envelope 40 is filled with the dry gas. By doing so,

heat deterioration of the phosphors is prevented.

Furthermore, the temperature is kept at the sealing temperature while the envelope is filled with the dry gas. At the same time, the sealing is performed while the envelope is evacuated with the turbo-molecule pump 72b. Note that when the turbo-molecule pump 72b is activated, the rotary pump 72c is also activated to lower the back pressure in the turbo-molecule pump 72b.

It is preferable to start the exhaust after the temperature in the heating furnace 71 reaches the softening temperature of the sealant. Before the temperature reaches the softening temperature, the airtightness of the outer edges of the front and back panels 10 and 20 is not high enough to produce a high vacuum in the envelope 40 even if gas is exhausted from the envelope 40. On the other hand, after the sealant is softened, the apertures between the front and back panels 10 and 20 along the outer edges are sealed. Also, the bonding member 73a is softened to seal the apertures between the connecting tube 73 and the ventilation slot 21a. As a result, when the gas is exhausted from the envelope 40, the pressure is reduced to produce a high vacuum (approximately 1.33×10^{-4}MPa, i.e., approximately several Torr).

By exhausting gas from the envelope 40 as has been described, pressure is evenly applied to the front

and back panels 10 and 20 from the outside. The degree of suction and exhaust is enough when the sealant is pressed to shrink due to the difference between the pressures in the envelope 40 and in the heating furnace and the front and back panels come to closer to each other so that the front panel touches the partition walls. For this reason, the suction and exhaust is slightly performed (for instance, approximately 0.08MPa).

When pressure is evenly applied to the front and back panels 10 and 20 from the outside, the front panel 10 comes into contact with the top ends of the partition walls on the back panel 20 as shown in Fig. 3. When the temperature is lowered in this state, the temperature of the sealant becomes lower than the softening temperature and the sealant hardens to seal the envelope 40. As a result, the front panel 10 and the entire top ends of the partition walls are kept in absolute contact in the sealed envelope 40.

Note that the temperature is increased not at one stroke to the sealing temperature that is slightly higher than the softening temperature of the sealant in the sealing process. The temperature is kept at lower than the sealing temperature for a certain period of time, for instance, at around 350℃ for 30 minutes, to burn out the binder material. This is effective at preventing the phosphor from deteriorating.

After the sealing process, the processing advances to the vacuum pumping process, the sealing process, and the discharge gas filling process to produce the PDP as in the case of the first embodiment.

(The Sixth Practical Example)

A specific explanation of the sixth practical example of the PDP producing method in which each of the processes is performed according to the fourth preferred embodiment will be given below.

In the sixth practical example, the PDP is manufactured according to the same temperature and pressure profiles as in the fourth practical example. The getter 76 is inserted into the getter tube 74 when the sealing has been performed and the temperature has been lowered to the room temperature. As the getter, vanadium, titanium, and iron alloy particles that are activated at 280℃ are used.

In the conventional vacuum pumping process, it takes around two hours to lower the pressure in the envelope to 1.3×10^{-11} to 1.3×10^{-10}. On the other hand, pressure can be lowered in around one hour in the vacuum pumping process of the sixth practical example.

For the PDP that has been produced according to the above-mentioned method, lifting rarely occurs in the outer regions. Also, the discharge properties are even

compared with the conventional method in which pressure is applied only with clips. The level of noise from the outer regions is reduced by approximately several to 10db. The voltage at the start of discharge decreases by approximately 5 to 10V. Furthermore, the discharge current decreases by approximately several to 10% and the effectiveness improves by around 10%.

Meanwhile, a comparative evaluation of the luminescence intensity (intensity/"y" chromaticity coordinate value) is performed on the phosphors of the PDP that has been sealed after dry gas is circulated as has been described and the PDP that has been sealed while the atmosphere is included in the PDP according to the conventional method. The comparative evaluation is performed by breaking the panel and irradiate Xe excimer lamp (with 173nm of wavelength). The luminescence intensity is improved by around 10% for the blue phosphor. Although the luminescence intensity is improved for all kinds of non-reactive dry gas, significantly improved for dry air.

Note that while the sealing process and the vacuum pumping process have been performed in the same apparatus in the first to fourth preferred embodiments, it is not the only case. The sealing process and the vacuum pumping process can be performed in different apparatuses.

Also, heat is not always applied to the envelope as a whole in the sealing process. It is possible to selectively apply a heat source such as the laser beam to the part where the envelope is to be sealed so as to selectively apply heat to seal the envelope. In this case, the phosphors are not directly heated. As a result, it is assumed that the phosphors are rarely deteriorated by heat in the sealing process even if dry gas is not introduced into the discharge space.

As has been described, the present invention is a method of producing a gas discharge panel that includes: an envelope forming step for forming an envelope by providing over a first plate a second plate so that the second plate faces a main surface of the first plate, on which partition walls for partitioning light emitting cells have been formed; a sealing step for sealing the envelope with a sealant along outer edges of the first and second plates; an exhaust step for exhausting gas from the envelope; and a filling step for filling the envelope with a discharge gas, wherein the exhaust step includes: a substep for evacuating the envelope; a substep for filling the envelope with a cleaning gas that includes as a constituent a gas that substantially causes no impurity in the discharge gas; and a substep for re-evacuating the envelope.

Also, the present invention is a method of

producing a gas discharge panel that includes: an envelope forming step for forming an envelope by providing over a first plate a second plate so that the second plate faces a main surface of the first plate, on which partition walls for partitioning light emitting cells have been formed; a sealing step for sealing the envelope with a sealant along outer edges of the first and second plates; an exhaust step for exhausting gas from the envelope; and a filling step for filling the envelope with a discharge gas, wherein the exhaust step includes: a substep for evacuating the envelope; and a substep for exhausting gas from the envelope while a cleaning gas is circulated through the envelope, the cleaning gas including as a constituent a gas that substantially causes no impurity in the discharge gas.

Unlike the conventional method, gas is not only exhausted from the envelope as in the case of the conventional producing method. According to these producing methods, gas is exhausted from the envelope after the envelope is filled with the cleaning gas or while the cleaning gas is circulated through the envelope. As a result, the concentration of impurity gas in the envelope can be swiftly (in a short period of time) lowered compared with the conventional method. The higher definition the gas discharge panel, the more significant the effective. This is because it takes

longer to lower the impurity gas concentration as the definition is increased in general.

Note that when gas is exhaust from the envelope after the envelope is filled with the cleaning gas, it is more preferable to exhaust gas after a certain period of time has elapsed since the envelope is filled with the cleaning gas.

Here, the sealant can be disposed between the first and second plates, the entire envelope can be heated at a temperature that is no lower than one of a softening point and a melting point of the sealant while a pressure in the envelope can be set lower than a pressure outside of the envelope, and the envelope can be cooled at the sealing step. Note that lead alloy can be used as the sealant.

As a result, the envelope is sealed so that the entire top ends of the partition walls almost come in contact with the plate that faces the partition walls.

Here, a step for inserting a getter into a container that is linked to an internal space of the envelope can be included between the sealing step and the exhaust step.

As a result, the impurity gas can be removed from the envelope more swiftly.

Here, the entire envelope can be heated at a temperature that is no higher than one of a softening

point and a melting point of the sealant at the exhaust step. Note that when the getter is used as in the case described above, it is preferable that the activation temperature of the getter is within the range of the heating temperature.

As a result, the impurity can be removed from the envelope more swiftly.

Here, the entire envelope can be cooled to a temperature that is higher than room temperature and no higher than one of the softening point and the melting point of the sealant at the sealing step.

By doing so, a process in which the temperature is lowered to the room temperature once and then increased to the exhaust baking temperature is not included the processing. As a result, the processing can advance to the next step, the exhaust step earlier.

Here, the sealing step can include: a substep for disposing the sealant between the first and second plates, and heating the entire envelope to a temperature that is no lower than one of a softening point and a melting point of the sealant while a dry gas is circulated through the envelope; and a substep for heating the entire envelope at a temperature that is no lower than one of the softening point and the melting point of the sealant while a pressure in the envelope is set to be lower than a pressure outside of the envelope,

and cooling the envelope.

By doing so, the sealing step is performed while the envelope is filled with the dry gas. As a result, the heat deterioration of the phosphors can be prevented.

Here, the sealant can be disposed between the first and second plates, sealed edges of the first and second plates can be heated at a temperature that is no lower than one of a softening point and a melting point of the sealant while a pressure in the envelope is set lower than a pressure outside of the envelope, and the envelope can be cooled at the sealing step.

Here, it is most preferable to use the discharge gas as the cleaning gas.

This is because there is no possibility that the cleaning gas is an impurity gas for the discharge gas with which the envelope is filled at the filling step, which comes after the exhaust step.

Here, a noble gas can be used as the discharge gas.

Here, the noble gas can include at least one of helium, neon, argon, and xenon.

Here, the light emitting cells can be formed by positioning a first group of parallel electrodes on the first plate orthogonally to a second group of parallel electrodes on the second plate with a distance between the first and second electrode groups.

Although the present invention has been fully described by way of examples with reference to the accompanying drawings, it is to be noted that various changes and modifications will be apparent to those skilled in the art. Therefore, unless such changes and modifications depart from the scope of the present invention, they should be construed as being included therein.

INDUSTRIAL USE POSSIBILITY

The method of producing gas discharge panel according to the present invention can be applied to manufacturing the PDP and the like that is used as the display such as the monitor of the TV set, the computer, and the like.